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Effect of Engine Rotation on Mechanical Water Pump and Microcontroller-Based Electric Water Pump for Liquid-Cooled Motor Engine on Coolant Temperature

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ABSTRAK

Sistem pendingin motor berpendingin cairan sangat penting dalam menjaga kinerja mesin. Penelitian ini membandingkan pompa air mekanik dan elektrik berbasis mikrokontroler untuk meningkatkan efisiensi pendinginan. Penelitian ini bertujuan untuk mengukur pengaruh kedua jenis pompa terhadap suhu mesin cairan pendingin. Penelitian ini menggunakan metode eksperimen, yaitu memasang kedua jenis pompa tersebut pada mesin dengan sistem pendingin cairan. Dalam penelitian ini juga digunakan komponen thermostat. Pengukuran dilakukan terhadap suhu cairan pendingin pada berbagai putaran mesin (RPM). Hasil penelitian menunjukkan bahwa pompa air elektrik berpengaruh signifikan terhadap suhu cairan pendingin. Pada suhu cairan pendingin, pompa air elektrik dengan thermostat memperoleh suhu cairan pendingin tertinggi pada putaran mesin 4500 RPM sebesar 80,6°C, sedangkan pompa air mekanik sebesar 84,25°C. Pada pengujian tanpa thermostat, pompa air elektrik memperoleh suhu dan debit cairan pendingin tertinggi sebesar 62,75°C, sedangkan pompa air mekanik memperoleh suhu sebesar 64,88°C.

Kata Kunci : pompa air mekanik, pompa air elektrik, thermostat, temperature.

ABSTRACT

A liquid-cooled motor's cooling system is essential in maintaining engine performance. This study compares mechanical and electric water pumps based on microcontrollers to improve cooling efficiency. This study aims to measure the influence of the two types of pumps on engine temperature. This study uses an experimental method, installing the two types on machines with liquid cooling systems. In this study, thermostat components are also used. Measurements are made on the temperature of the coolant at various engine revolutions (RPM). The results showed that the electric water pump significantly affected the temperature of the coolant. At the coolant temperature, the electric water pump with thermostat obtains the highest coolant temperature at 4500 RPM engine speed of 80.6°C, while the mechanical water pump is 84.25°C. In the thermostat-less test, the electric water pump obtained the highest temperature and coolant discharge of 62.75°C, while the mechanical water pump achieved a temperature of 64.88°C.

***Keywords**: mechanical water pump, electric water pump, thermostat, temperature.*

INTRODUCTION

Engines with liquid cooling are essential parts of motor vehicles, especially for maintaining the engine's temperature. The liquid cooling system in motorcycle engines is in great demand because it efficiently maintains the engine's working temperature so that overheating does not occur. Search cooling systems on motorcycles are widely used in engines with relatively high compression ratio [1].

The cooling process is an example of dissipating heat energy and is essential in its use. Motor vehicles require cooling for the engine to reach optimal and stable conditions and to keep the components from damage. To get the engine cooling process, it can be done using a tool, namely a radiator [2].

Motorcycles that use liquid cooling require a device to circulate coolant on the cylinder wall and

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cylinder head (water jacket) [3]. A device that is often used on liquid-cooled motorcycles is a mechanical water pump. The mechanical water pump on a motorcycle is an essential component in the liquid cooling system in the internal combustion chamber, whose role is to drain the coolant from the engine circulation path (water jacket) to the radiator [4]. In a radiator, there is a process of changing hot and cold temperatures, mostly through the convection heat transfer. This heat exchange is caused by a high-temperature difference between the liquid that experiences an increase in temperature and the liquid that the radiator has cooled [4].

Various problems encountered in mechanical water pumps, such as the rotation speed of the water pump, inhibit the rotation of the mechanical water pump, which adjusts to the needs of the machine. Mechanical water pumps work with a constant flow rate, i.e. the flow rate cannot be varied, and the heat transfer rate varies. During cold and heating conditions, there is no need for cooling. However, because the mechanical water pump is permanently driven, there is a loss of power, which thus reduces fuel efficiency. To overcome this limitation, mechanical water pumps are proposed to be converted into electric water pumps [5] The water pump used on motorcycles is a type of mechanical water pump that is mechanically driven by a crankshaft through gears. However, mechanical water pumps have disadvantages, such as the coolant flow rate being tied to the engine rotation so that temperature control becomes less effective; in some cases, such as the idle position after the engine is running under high load, the water pump must provide sufficient flow and pressure to cool the engine at low engine rotation speed allowing for damage to the curved cylinder head [3] Electric water pumps are an alternative to overcome these weaknesses [6].

Electric water pumps can control liquid flow separately from the engine rotation to drain liquid according to the engine's cooling needs. This is expected to stabilize the engine temperature and maintain the coolant discharge. The thermostat is one of the components in the engine cooling system that regulates the flow of coolant so that the engine temperature immediately reaches the working temperature and keeps the engine temperature at the ideal working temperature [7] In the application of the thermostat, there is a weakness when the temperature is low in the engine; the work of the mechanical water pump becomes burdened because the coolant does not circulate to the radiator due to the closed thermostat valve, which provides a load on the engine. In some cases, if the thermostat is damaged, there is no early notification of the damage to the component because the thermostat is a component that cannot be identified if there is direct damage [8]

Mechanical pumps are directly driven by the engine via belts or gears, causing their flow rates to depend on engine RPM and resulting in parasitic losses that reduce fuel efficiency [9]. In contrast, electric water pumps (EWPs) utilize electric motors controlled by the ECU, enabling independent coolant flow regulation based on temperature requirements. Research demonstrates that PID-controlled EWPs can maintain engine temperature within ±2°C, significantly more precise than mechanical pumps' ±10°C fluctuations [10]. EWPs also provide power savings of 1-2 HP by eliminating crankshaft load [11], with the added capability of post-engine shutdown operation - a critical feature for turbocharged engines in motorsports applications [12]. Furthermore, advanced diagnostic systems in EWPs can detect early failures through IoT sensors, while mechanical pumps typically only show failure symptoms after complete breakdown [13]. Despite higher initial costs, EWPs' superior efficiency, temperature control, and reliability make them ideal for modern vehicles.

Based on the background above, the researcher conducted a study by analyzing the effect of a microcontroller-based electric water pump for a liquid-cooled motor engine. It is hoped that by conducting this study the effect of a mechanical water pump and an electric water pump on the temperature of the water coolant.

MATERIALS AND METHODS

This study uses an experimental type of research and quantitative research methods because this research obtains information that can be calculated and measured factually in the form of numbers. Before conducting testing, there are several processes to produce a tool that is suitable for testing. Several processes can produce a series of microcontroller-based electric water pumps,

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and system design needs to be carried out in a mathematical system in order to achieve the goals of the research can be achieved.

The use of research variables includes independent variables using the type of mechanical water pump and electric water pump and a comparison of the presence and absence of a thermostat at a variation of engine speed of 1500-4500 RPM with an interval of 1000 RPM; the dependent variable is the temperature of the coolant; and the control variable uses a 135 CC motorcycle, type of radiator water, initial test temperature of 33 ° C, and test time of 5 minutes.

Design of a microcontroller-based electric water pump in the liquid-cooled machine using the main components, namely: Arduino Uno is a microcontroller as a control system for all-electric water pump series; Electric water pump as an actuator for a liquid cooling system that is fully controlled by a microcontroller; The temperature sensor DS18B20 is a coolant temperature reader that will later input the temperature as a trigger for the rotation of the electric water pump. The flow meter sensor YF-B6 is a coolant discharge reader in the coolant circulation system. Stepdown LM2956 is used to lower the voltage from a 12-volt battery to 5 volts for the microcontroller's leading power; MOSFET IRFZ44N is a power controller that goes to the electric water pump. Diode 1N4007 as a voltage rectifier AC initially becomes DC for electric water pump motors; 12-volt battery: Used for the main power supply in microcontroller-based electric water pump systems. Figure 1 shows the settings of research tools on liquid-cooled motorcycle media. This diagram illustrates the fluid flow cycle in a liquid-cooled engine system. The heat that the coolant has absorbed comes out of the engine part and goes to the radiator to cool. Inside the engine cylinder, the fluid absorbs the working temperature of the engine, which then causes the fluid to become hot so that this hot coolant moves towards the radiator through the circulation flow (radiator hose). The fluid is cooled inside the radiator before starting the next flow cycle. This diagram uses colours and arrows to make it easier to understand how hot and cold coolant flows through the circulation system and how to find out how the liquid cooling system works in a liquid-cooled machine.

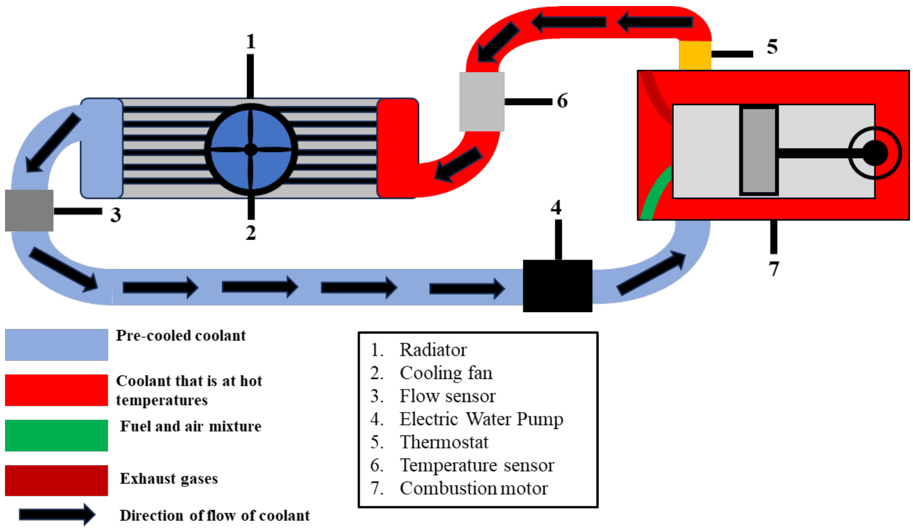

Figure 1. Tool Settings on Liquid Cooled Motor Engines

Figure 2 shows the electronic circuit for a microcontroller-based electric water pump using Circuit Designer software. The system uses a microcontroller as the control center of the electric water pump. The microcontroller uses an electronic circuit designed to detect the water level in the tank through a water level sensor. The data from these sensors is then processed by a microcontroller, which automatically activates or deactivates the electric water pump according to the detected conditions. In addition, the series is equipped with a wireless communication module to monitor and control the system remotely and a relay to control power to the pump. The system was built to improve energy efficiency and ensure operational consistency.

Figure 3 shows a diagram of an electronic circuit that depicts the control system using an Arduino microcontroller, consisting of main components such as Stepdown Lm2956, Arduino Uno, electric water pump, MOSFET, flow meter sensor, LCD screen, and Bluetooth module. The 12V 5Ah battery is the primary power source connected to the Stepdown LM2956 to lower the voltage from 12V to 5V, then powering the microcontroller. The Arduino controls the entire system, including controlling the water pump through the MOSFET, measuring the coolant discharge using a sensor flow meter, and displaying information on a 20x4 I2C LCD screen. The electric water pump is turned on or off based on a signal from the Arduino, whose percentage input is according to the temperature sensor reading DS18B20. The 20x4 I2C LCD information includes coolant discharge, calculation of the volume passed through the sensor flow meter, coolant temperature, and electric water pump working percentage.

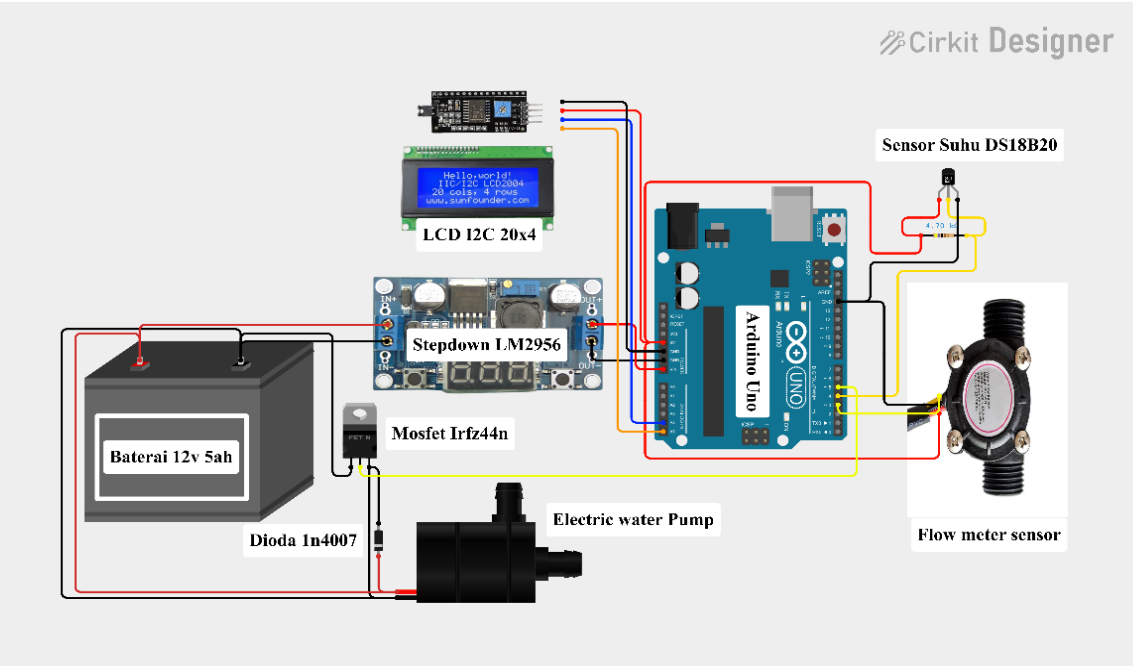

Figure 2. Electronic Networks

Table 1. Specification electric water pump

No	Parameters	Value
1	Part Number	1K0965561J B
2	Type	Electric Water Pump
3	Brand	FLY
4	Size	110mmX78mm
5	Voltage	12 Volt
6	Material	Plastic and Iron

The tool design is in schematics and uses Easyeda software to combine each component pin with the controller. The electronic circuit used is the Arduino Uno controller, which includes several sensors such as a temperature and discharge reader in the coolant and a DS18B20 temperature sensor whose data pin will be connected to the D4 digital pin on the Arduino Uno [14] To read the change in coolant temperature, there is a sensor water flow meter whose data pin is connected to the Arduino Uno on the D3 digital pin as a sensor that reads the coolant velocity rate and calculates it into the overall volume [15] Arduino uno as a controller regulates the input signal from the DS18B20 temperature sensor and the sensor water flow meter, whose signal will be displayed on the 20x4 I2C LCD screen and to the electric water pump as a coolant pump on the engine. The input voltage source for the Arduino Uno is 5 V, which is used in vehicles with a battery voltage of 12 V. The LM2596 step-down is used to reduce the battery voltage from 12 V to 5 V [16] The voltage output from the step down is connected to the Vin (positive +) and GND (negative-) pins. When the DS18B20 sensor detects an increase in the temperature of the coolant by 35°C, the data signal from the temperature sensor will be forwarded to the Arduino uno on the digital pin D5 to open the G pin (gate) on the irfz44n mosfet as a voltage conductor to the electric water pump with the S

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pin (source) as the negative voltage controller, so that the electric water pump can operate according to the temperature rise in the coolant. The following is Figure 2, which shows an electronic circuit for a microcontroller-based electric water pump.

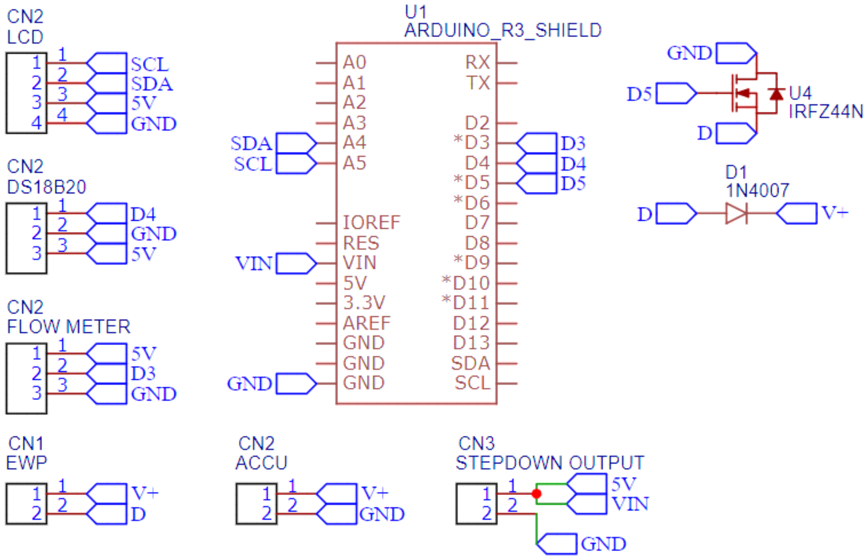

Figure 3. Microcontroller-Based Electric Water Pump Series

The data collection method in this study for either using a mechanical water pump with or without a thermostat is as follows:

- First, open the vehicle body cover, then install the thermostat, install the flow meter sensor and temperature sensor on the radiator hose, assemble the microcontroller system on the flow meter and temperature sensor
- Turn on the engine and test with an engine speed of 1500-4500 RPM.
- Record the initial coolant temperature of 33°C, then collect data. This process is repeated four times at each RPM.
- Repeat for testing without a thermostat.

Meanwhile, the data collection method in this study for either using an electrical water pump with or without a thermostat is as follows:

- First, remove the mechanical water pump from the engine, install the thermostat, install the unique timing chain cover for the electric water pump
- Assemble the microcontroller system on the electric water pump, flow meter, and temperature sensor
- Turn on the engine, and test with an engine speed of 1500-4500 RPM
- Record the initial coolant temperature at 33°C, then collect data. This process is repeated four times at each RPM.
- Repeat for testing without a thermostat.

RESULTS

In this study, tests were conducted to compare the performance of mechanical and electric water pumps in maintaining the temperature of coolant in liquid-cooled machines. Tests were carried out on various rotation conditions of 1500 RPM-4500 RPM with an interval of 1000 RPM. Each test lasted 5 minutes, and a thermostat was absent. Here are the results obtained.

The following is a table of research data for mechanical water pumps with and without thermostats and electric water pumps with and without thermostats. The first test can be seen in Table 2, the second test can be seen in Table 3, the third test can be seen in Table 4, and the fourth test can be seen in Table 5.

Figure 4. displays the data on mechanical and electric water pumps using thermostats based on the coolant temperature. In the test graph, the mechanical and electric water pumps experienced

a significant spike in coolant temperature corresponding to the engine revolution (RPM). At 1500 RPM engine rotation in Figure 4. the temperature reached by the mechanical water pump is 70.13 °C; at 2500 RPM, the coolant temperature of the mechanical water pump is 71.50°C with a percentage increase of 2%, for the engine rotation of 3500 RPM the temperature is 72.25°C with a percentage increase of 5%. At 4500 RPM, the temperature of the mechanical pump reaches up to 80.25°C with a percentage increase of 12%, which indicates that the thermostat is open and can circulate the coolant to the radiator to be cooled.

Table 2. Testing of mechanical water pumps with thermostats

Engine Rotation (RPM)	**Temperature (°C)**				
	Measured				**Average**
1500	70	71	71.5	73	71.38
2500	71	69.5	72.5	73	71.50
3500	75	74,5	76	75.5	75.25
4500	85.5	84	83	84.5	84.25

Table 3. Testing of mechanical water pumps without thermostat

Engine Rotation (RPM)	**Temperature (°C)**				
	Measured				**Average**
1500	55	53.5	54	56	54.63
2500	57	59	58,5	58	58.13
3500	60	63	61.5	62.5	61.75
4500	65	64	63.5	67	64.88

Table 4. Testing of electric water pump with thermostat

Engine Rotation (RPM)	**Temperature (°C)**				
	Measured				**Average**
1500	67	63	63	66.5	64.88
2500	70	69.5	68	69	69.13
3500	73	73	72	73	72.75
4500	79.5	81.5	81	80.5	80.63

Table 5. Testing of electric water pump without thermostat

Engine Rotation (RPM)	**Temperature (°C)**				
	Measured				**Average**
1500	48	49	48	48.5	48.38
2500	54	55	51	52	53.00
3500	58.5	59	60.5	57.5	58.88
4500	61	61.5	63	65.5	62.75

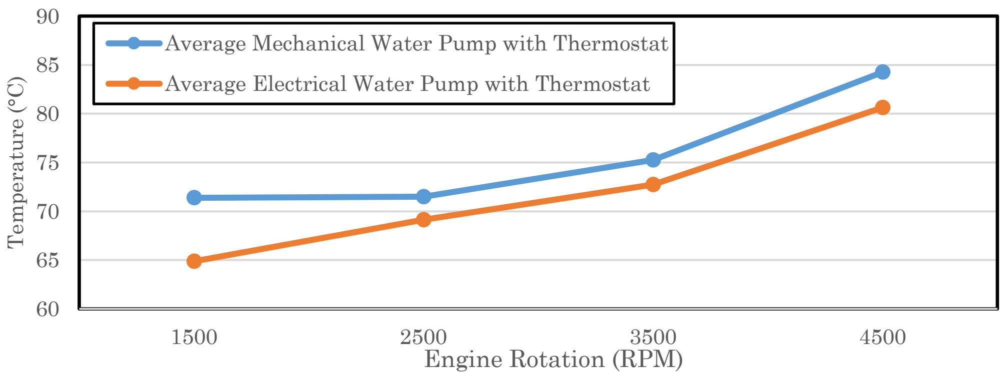

Figure 4. Temperature Comparison between Mechanical Water Pump and Electric Water Pump with Thermostat

The coolant temperature with the use of an electric water pump at 1500 RPM engine speed produces a temperature of 64.9°C (Figure 4). At 2500 RPM, the coolant temperature is 69.1°C with a percentage increase of 7%. Then, at 3500 RPM engine speed, the coolant temperature is 72.8°C with a percentage increase of 5%. In the engine speed test, 4500 RPM produces a temperature of 80.6°C with a percentage increase of 11%. The decrease in the coolant temperature in an electric water pump is compared to a mechanical water pump that uses a thermostat. At 1500 RPM engine rotation of 8%, 2500 RPM engine rotation of 3%, 3% engine rotation of 3500 RPM, and 4500 RPM engine rotation of 4%, the decrease in coolant temperature makes the electric water pump consistent in maintaining the coolant temperature.

Based on the coolant temperature, Figure 5 displays data for mechanical and electric water pumps without a thermostat. In the test graph, mechanical and electric water pumps experience a significant increase in coolant temperature according to engine rotation (RPM). At 1500 RPM, the temperature reached by the mechanical water pump is 54.64°C; at 2500 RPM, the coolant temperature of the mechanical water pump is 58.13°C with a percentage increase of 6%; for the engine speed of 3500 RPM, the temperature is 61.76°C with a percentage increase of 6%, and at the test of 4500 RPM the temperature of the mechanical pump reaches up to 64.88°C with a percentage increase of 5% which indicates that without the use of the thermostat, the coolant can circulate generally from the beginning of the test.

In Figure 5, the coolant temperature with the use of an electric water pump at 1500 RPM engine speed produces a temperature of 48.38°C. At 2500 RPM, the coolant temperature is 53°C with a percentage increase of 10%. Then, at 3500 RPM engine speed, the coolant temperature is 58.88°C with a percentage increase of 11%. In the engine speed test, 4500 RPM produces a temperature of 62.75°C with a percentage increase of 7%. The decrease in coolant temperature in mechanical water pumps is compared to electric water pumps without a thermostat. At 1500 RPM engine rotation of 13%, 2500 RPM engine rotation of 10%, 3500 RPM engine rotation of 5%, and 4500 RPM engine rotation of 3%, the coolant temperature decrease makes the electric water pump consistently maintain the coolant temperature.

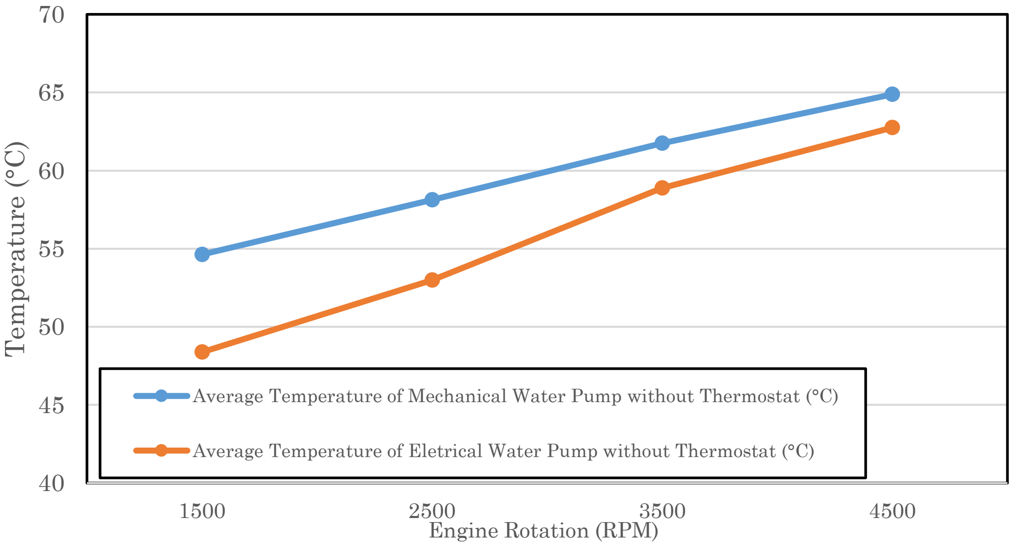

Figure 5. Temperature Comparison Chart of Mechanical Water Pump and Electric Water Pump Without Thermostat

SUGGESTION FOR FUTURE RESEARCH

The engine speed has a direct relationship with the coolant temperature. The higher the engine speed (RPM), the higher the working temperature produced by the engine. This is because the higher the engine speed, the more heat will be generated from each combustion cycle that occurs. With the thermostat on the mechanical water pump and electric water pump, the coolant temperature will increase significantly. Because the thermostat will work when the coolant temperature reaches ±80°, if the temperature has not reached that temperature, the coolant will only circulate in the part that does not pass through the thermostat. Some things that the author can suggest to other researchers are the use of better flow meter sensors and other temperature sensors, adding an IOT (Internet of Things) monitoring system to make it easier to read the test system using a cellphone, conducting tests at higher engine speed loads to see the decrease in engine temperature that can be achieved by using an electric water pump.

CONCLUSION

With a percentage of work according to the increase in coolant temperature. It can be concluded that the ability of the electric water pump with a thermostat to maintain engine temperature from overheating is better than that of a mechanical water pump. While on the EWP, the engine speed may not directly affect the rotation of the electric water pump. The rotation of the electric water pump is affected by the temperature of the coolant. The temperature increases with increasing engine speed (RPM), but the increase is more controlled in the electric water pump with a thermostat because the electric water pump works electronically.

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